U.S. Coast Guard Research and Development Center

1082 Shennecossett Road, Groton, CT 06340-6096

Report No. CG-D-03-01

Automatic Identification System (AIS) User Requirements

December 2000
Final Report

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Marine Safety and Environmental Protection (G-M)
and
Systems (G-S)
Washington, DC 20593-0001

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Technical Report Documentation Page

1. Report No.
CG-D-03-01

2. Government Accession Number

3. Recipient's Catalog No.

4. Title and Subtitle
Automatic Identification System (AIS) User Requirements

5. Report Date
December 2000

6. Performing Organization Code
Project No. 2410.5

7. Author(s)
Michael Edwards and David Pietraszewski

8. Performing Organization Report No.
R&DC 436

9. Performing Organization Name and Address
U.S. Coast Guard
Research and Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Organization Name and Address
U.S. Department of Transportation
United States Coast Guard
Marine Safety and Environmental Protection (G-M)
and Systems (G-S)
Washington, DC 20593-0001

13. Type of Report & Period Covered
Final

14. Sponsoring Agency Code
Commandant (G-MWV), (G-SCT)
U.S. Coast Guard Headquarters
Washington, DC 20593-0001

15. Supplementary Notes
The CG R&D Center's technical point of contact is LT Michael Edwards, (860) 441-2825, email medwards@radioaid.rdc.uscg.mil

16. Abstract
Automatic Identification System (AIS) is a new technology that should improve situational awareness for the mariner by providing navigation information such as the names, positions, courses, and speeds of vessels in the immediate vicinity. Over the past decade, there has been a great deal of research to support the standards for AIS set forth by the International Maritime Organization (IMO), International Telecommunications Union (ITU), International Electrotechnical Commission (IEC) and International Association of Marine Aids-to-Navigation and Lighthouse Authorities (IALA). However, there has been little work done to develop the AIS users' needs relating to this technology. Without a relevant and easy to use interface, AIS will not be an effective tool for the mariner. This report attempts to describe and qualify some of the requirements for the user interface based on AIS tests conducted in San Francisco Bay, the Baltic Sea and British Columbia. Discussed are issues involving display features such as vessel icons, Vessel Traffic Service (VTS) information, carry aboard units, and workload issues related to the new technology. Coupled with a user-friendly interface, the AIS information should allow the mariner to focus more time on the navigation situation around them thus increasing situational awareness and safety.

This report only scratches the surface. Areas that still need to be explored include enhanced AIS issues such as direct sensor information, shore radar integration, intermodal information, environmental mishaps, and search and rescue responses.

17. Key Words
Automatic Identification System, AIS, UAIS, San Francisco Bay

18. Distribution Statement
This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161.

19. Security Class (This Report)	20. Security Class (This Page)	21. No of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	25	

EXECUTIVE SUMMARY

The United States Coast Guard (USCG) is focused on preventing mishaps at sea. Mishaps destroy millions of dollars of property, cause environmental damage, and take many lives in our ports and waterways each year. With an increase in situational awareness, many of these maritime casualties and mishaps can be avoided. Current situational awareness, or the mariner's perception of his environment, uses a vessel's own radar and the mariner's scrutiny to safely navigate. Often these methods are enhanced with information from a Vessel Traffic Service (VTS), navigation signals such as lights or sounds, or by radiotelephone communications. During times of good visibility and low traffic density, these methods are timely and informative enough to help the mariner safely navigate. However, in areas of high traffic, low visibility, or blind spots that can affect radar, visual or radio communications, situational awareness can be significantly hampered.

Automatic Identification System (AIS) is a promising technology that will be implemented over the next decade to provide mariners with additional information to increase situational awareness. AIS will automatically broadcast, among other things, the vessel's navigation information such as name, position, course and speed. Any vessel within Very High Frequency (VHF) radio range similarly equipped with an AIS unit will detect the other units and receive their corresponding information. Much work over that last decade has been focused on the internal functionality of the AIS units themselves. However, little has been done to determine what information is useful to the mariner and how that information should be displayed on the bridge of a ship. Without an efficient and effective user interface, the AIS information and equipment may become a burden rather than provide the intended situational awareness.

This report outlines some specific user requirements for this new technology. It is intended for groups interested in developing AIS user requirements as they relate to system usage and the user's interface. It combines subjective feedback from three AIS-like tests completed in the Baltic Sea, British Columbia, and most rescently in San Francisco Bay. The issues of vessel icons, information displayed, and VTS radar data are explored. Some possible effects on the mariners' work environment are also discussed. Finally, future work in expanding areas such as enhanced AIS, and digital networks are presented.

TABLE OF CONTENTS

CHAPTER ***PAGE***

LIST OF FIGURES

Figure **Page**

LIST OF ACRONYMS

ACRONYM	DEFINITION
ARPA	Automatic Radar Plotting Aid
AIS	Automatic Identification System
BAFEGIS	Baltic Ferry Guidance and Information System
COG	Course Over Ground
CPA	Closest Point of Approach
DGPS	Differential Global Positioning System
ECDIS	Electronic Chart Display System
GPS	Global Positioning System
HMI	Human Machine Interface
IALA	International Association of Marine Aids-to-Navigation and Lighthouse Authorities
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
ITU	International Telecommunications Union
MTS	Maritime Transportation System
NDBC	National Data Buoy Center
NOAA	National Oceanographic and Atmospheric Administration
PC	Personal Computer
PDA	Personal Digital Assistant
PORTS	Physical Oceanographic Real Time System
R&D	Research and Development
SOG	Speed Over Ground
UAIS	Universal Automatic Identification System
USCG	United States Coast Guard
VDC	Vessel Data Card
VHF	Very High Frequency
VHF-FM	Very High Frequency - Frequency Modulation
VTS	Vessel Traffic Service
WISP	Wireless Internet Service Provider

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1. INTRODUCTION

The universal Automatic Identification System (AIS) is an emerging technology that uses digital VHF broadcast technology to send vessel movement data. Various committees of the IMO, ITU, IEC and IALA are working on finalizing the capabilities of the AIS unit. As the committee work nears completion, the effort to inform the marine public and industry about the capabilities and limitations of AIS has increased in importance. The feedback from the San Francisco Bay demonstration supports this effort.

AIS will allow mariners to view navigation data supplied by other similarly equipped vessels. Since the information that comes from the AIS equipment is digital in form, it is necessary to identify the mariner's requirements for how this information should be converted and displayed so that it can be properly interpreted. Proper interpretation is critical to realizing the safety and mobility goals of AIS technology. This summary presents and contrasts some initial findings from the San Francisco Bay demonstration with the observations reported in two other similar studies. The other two studies were conducted in the Baltic Sea and in British Columbia by separate organizations. This summary looks at issues surrounding:

- How to display and label an AIS target on an independent display. How much information is too much?
- Redistribution of Vessel Traffic Service (VTS) radar targets and voice reports. How helpful and accurate are they when combined with AIS reports?
- How to represent meeting situations between vessels. Can AIS do this using intended track lines and Closest Point of Approach (CPA)?
- AIS information on digital networks. A brief introduction to the possibilities of digital AIS information flow.
- Effects of AIS on the mariners' work environment. Can waterway safety and mobility goals be realized?

All three studies collect and report comments by mariners that are related to these issues. This summary collects and discusses some of the common issues. This summary is only an initial look at the impact AIS technology could have on a marine area like San Francisco Bay. There are many other important ideas that need to be investigated.

2. *THE SAN FRANCISCO BAY DEMONSTRATION*

The USCG Research & Development Center began an AIS-like demonstration in San Francisco Bay in September of 1997. The goal is to provide mariners in the Bay with real-time information about vessel movements, and meteorological and hydrographic conditions. The demonstration gives the mariner exposure to the timely information that AIS can provide, so that they might better understand AIS's potential collision avoidance, mobility and planning benefits.[1] Some examples of real-time data provided to our research participants in San Francisco are: vessel position, course over ground (COG), speed over ground (SOG), tidal height, current direction and velocity; and wind direction and velocity.

2.1 System Overview

Real-time data comes from several sources - vessels, sensors, and the USCG San Francisco VTS computer data base. There are eleven participating vessels equipped with AIS-like units depicted in Figure 1. The unit transmits the vessel's (D)GPS positions, COG, and SOG via a wireless Internet service provider (WISP) to a server in our laboratory in Connecticut.[2] This is one area where this demonstration differs from true universal AIS. Universal AIS is designed to operate independently of a shore-based infrastructure. By using the WISP, our experimental equipment is tethered to a shore communications provider. The R&D Center server distributes the received data, seconds later, to the participating vessels by the same WISP link . This gives the mariner the "look and feel" of real-time AIS.[3] The use of the WISP is temporary, and will be replaced by true universal AIS technology as that equipment becomes available.

[1] At the time this paper was written, the International Telecommunications Union (ITU)-R AIS standard and International Electrotechnical Commission (IEC) test methods were in draft form.
[2] When the demonstration started, in 1997, AIS technology was not available. The WISP approach was chosen to provide the data communications to and from the participating vessels.
[3] Our vessel update rate is constant. Unlike AIS, no attempt is made to vary the update rate with the speed or rate-of-turn of the vessel.

2.2 Enhanced AIS Data Sources

Hydrographic and meteorological sensor data are gathered from a web site maintained by the National Oceanographic and Atmospheric Administration (NOAA) and the National Data Buoy Center (NDBC)[4]. The NOAA term for this data is PORTS[5] for Physical Oceanographic Real-Time System. Like the transponder data, the server distributes the PORTS and NDBC buoy data to the vessels logged on as clients. There are nine PORTS sites in San Francisco Bay that report wind, temperature, pressure, tide, current, and salinity data. The single NDBC report comes from the "SF" entrance buoy eight miles outside the Golden Gate. It reports wind direction, speed and gusts, as well as wave height and period.

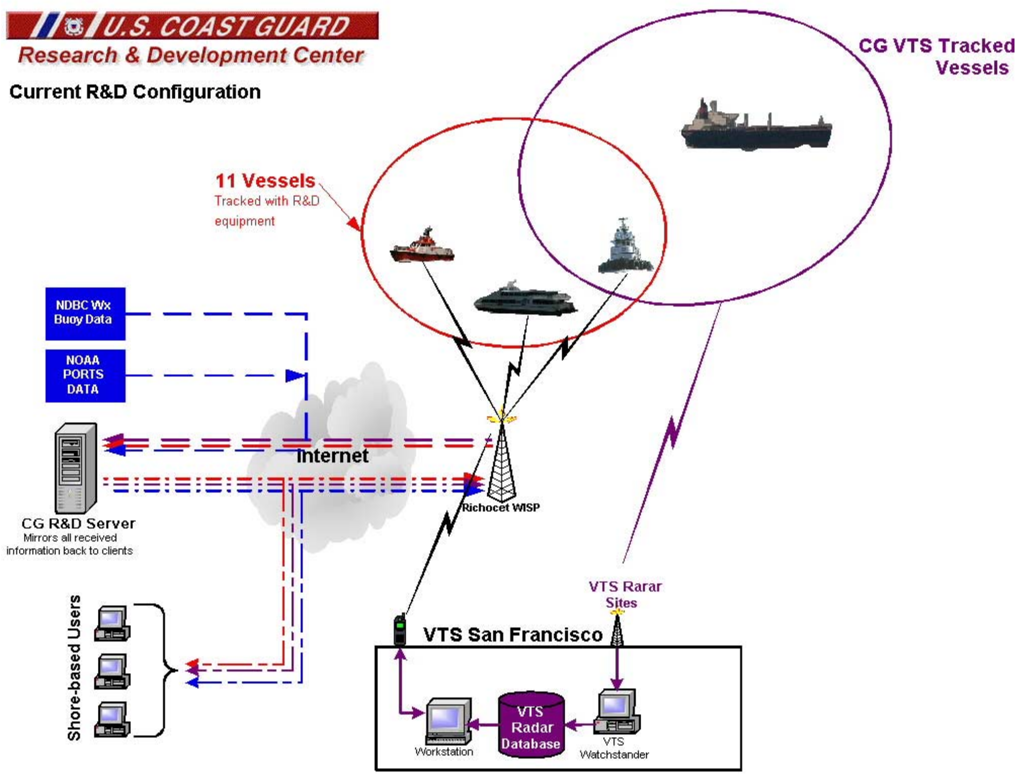

Figure 1. San Francisco Bay System Configuration

The final source of information comes from the Vessel Traffic Service (VTS) in San Francisco. It is located on Yerba Buena Island. VTS operators use radar sites located throughout the Bay to measure vessels' position, COG, and SOG and they associate this radar-derived information with identification of the targets. This compilation of radar and operator information is transmitted

[4] NDBC information can be found at: http://www.ndbc.noaa.gov/realtime.shtml

[5] PORTS information can be found at: http://www.co-ops.nos.noaa.gov/d_ports.html

through the R&D Center server to the participants' display. This gives the participants information about twenty additional vessels, on average, that are significant factors in their navigation planning. The addition of the VTS radar data, NOAA PORTS data, and NDBC buoy data goes beyond the ship-to-ship AIS and into areas of Enhanced AIS. These are examples of what could be added to AIS.

Enhanced AIS augments AIS shipboard-derived information with shore-based information - like VTS radar target identification. These enhancements give the participants in San Francisco a unique opportunity that is not currently shared by any other group testing AIS technology. The participants in San Francisco are afforded an opportunity to work and operate daily with technology and data that won't be implemented for several years. The addition of the VTS radar data provides the participants with a working AIS-like view of traffic in San Francisco Bay that represents the number of vessels expected to carry AIS devices by the year 2006.[6] Our participants continuously evaluate and use the AIS-like data and display. In many cases, they incorporate it into their daily operations. The participants in San Francisco Bay view this research project as a valuable new tool. The value manifested itself when they realized how the AIS-like data improves the safety and efficiency of their jobs. They possess a mature operational -- not experimental -- understanding of what the technology will provide and continue to provide opinions about what they will need in the future. They have become a unique and insightful community with respect to what AIS means for marine operations and what future AIS enhancements should be considered.

[6] The 2006 date estimate is based on the IMO carriage requirements for AIS installation.

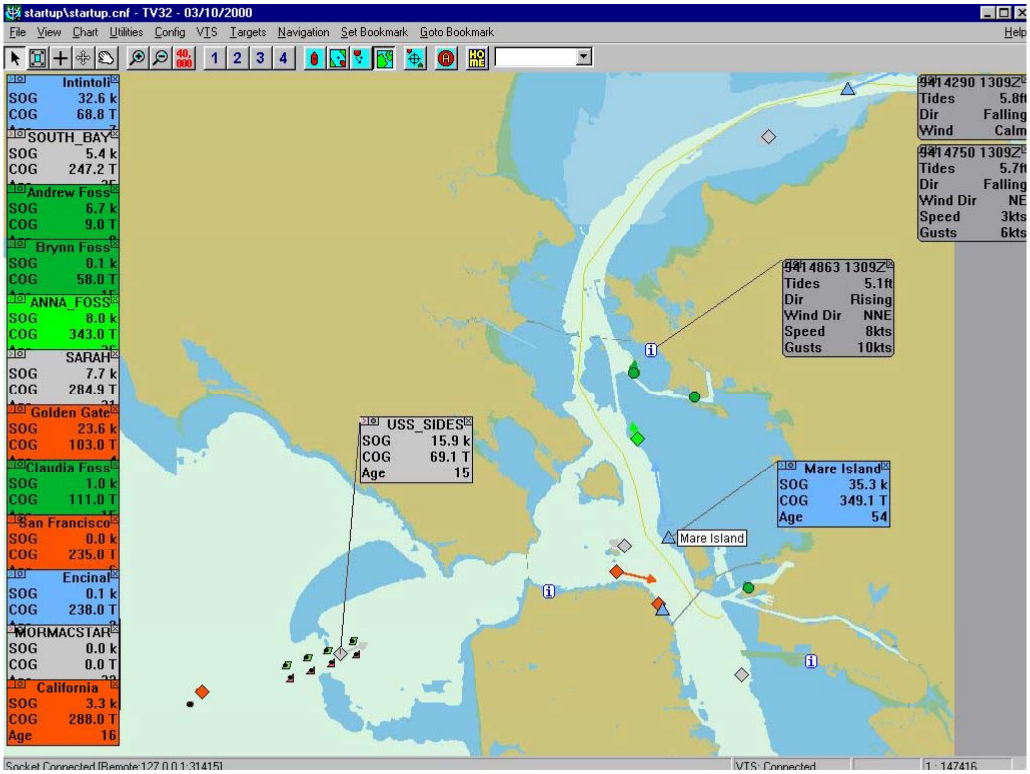

Figure 2. TransView display using a simplified vector chart as a backdrop

2.3 The San Francisco Bay Demonstration's Display

The critical part of this AIS technology, from the operator's perspective, is the display of the information. Part of our research is to determine what information the mariner wants and how they want it displayed. For the demonstration, the information flowing to the vessels from the server is displayed using government-owned software - called TransView. TransView displays the vessel's movement data, PORTS, and NDBC buoy data on a nautical chart-like background. The chart can be either vector or raster. Figure 2 shows one of many possible display options for TransView using simplified vector data.

In the figure 2 example, nine of the eleven vessels equipped with the AIS-like transponders are shown, including the fast ferry MARE ISLAND. These vessels are depicted on the chart as vessel icons. The TransView icon options are similar to the "Draft AIS Target Symbols" recommended by the Human Machine Interface (HMI) subgroup of IEC Working Group 8 (WG8) AIS. In addition, information such as vessel name, COG, and SOG are shown in the vessel data cards (VDC) on the left.

The type case of the characters used to spell the vessel name is chosen based upon the source of the information. If the first letters of the name are capitalized and the remaining letters lower case, the reports are from the AIS-like transponders. Figure 2 also shows four vessels tracked by the VTS operators, like the USS SIDES. To distinguish them from the vessels with transponders, the radar-tracked vessels have their names in all capital letters.[7] Data from the NOAA PORTS sites and NDBC buoy are indicated in the gray boxes on the right. The PORTS sites and NDBC buoy are shown on the display with lower case letter " i " icons inside a small white box.

The user can configure the display to include as little or as much of the vector chart as necessary. Raster charts can also be loaded and used to display information. Figure 3 shows an example of a raster chart background. Here the vessel labeled "CHERY_GAL" has just transitted under the Golden Gate Bridge. Other utilities such as a distance calculator, latitude and longitude indicator, and a facility that allows logging and playback of recorded data files, are also features of TransView.

Approximately eighty people have access to this information using TransView. They work for twenty different organizations ranging from fast ferry operators, to tug captains, to environmental researchers, to vessel dispatchers[8]. Each of these users have different ideas about what should and should not be displayed. We realized early in our research that different groups of users have different needs for information. The improvements to the TransView display over the last several years directly reflect the needs and wants of the participants in San Francisco. Through a series of training sessions, interviews, etc., we have been able to collect general subjective feedback about the display and the information it

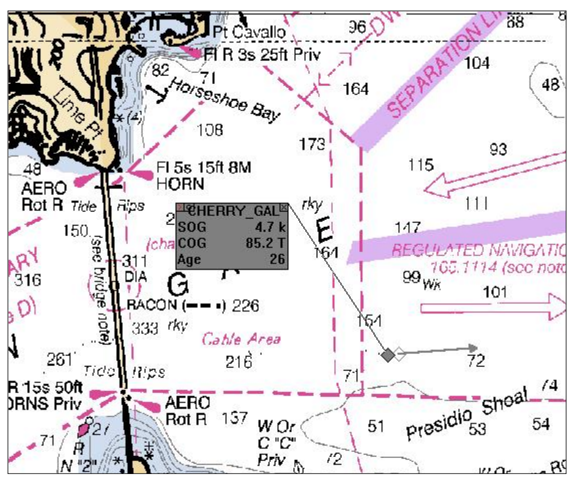

Figure 3. TransView display using a raster chart as a backdrop

[7] The colors of the vessel icons and VDCs, in this case, are user defined and set. Coloring can be another method for differentiating vessels of a certain type, cargo, size, etc.
[8] A list of our research participants can be found at http://radioaid.rdc.uscg.mil/sfbay/part_list.html

should provide.[9] We also looked at how the addition of AIS technology could affect work and environmental issues such as safety, communication, stress, and workload.

3. BALTIC FERRY GUIDANCE AND INFORMATION SYSTEM (BAFEGIS) REPORT

The BAFEGIS Project[10] consists of three separate studies relating to a series of AIS and Electronic Chart Display Information System or ECDIS tests performed in the South Baltic Sea. The tests, which began in January 1997 and are to conclude in June 2000, are a joint Swedish-German project carried out with four vessels and two VTS stations. The goal of the project was to test AIS equipment under actual maritime conditions.

4. BRITISH COLUMBIA AIS TEST

In the summer of 1999, a Canadian Coast Guard Cutter and three Princess Cruises' vessels participated in a project to test AIS-like equipment in British Columbia[11]. The objective was to gain operational experience with AIS technology, and to try to formulate recommendations on how to effectively use AIS on an operational ship's bridge. The bridge teams of the four vessels recorded encounters with other "AIS equipped" vessels, and evaluated display options and the impact access to the information had on vessel operations.

5. AIS DISPLAY AND WORK ENVIRONMENT ISSUES

AIS provides a unique capability to the mariner. It broadcasts a vessel's navigation information. This navigation information was previously "locked up" onboard each ship -- for the most part unavailable to other vessels. Before AIS, the mariner was aware of his own ship's information such as name, call sign, draft, length, beam, position, course, speed, etc., but he or she had to go elsewhere to get information about other vessels.

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[9] The sample set here is very small. Due to the limited scope of our research group, no statistical analysis was attempted.
[10] This report is a product of the Swedish Maritime Administration.
[11] A copy of this report can be downloaded at http://www.chamber-of-shipping.com.

Before AIS, information about another ship's position, course, and speed could be estimated using a ship's radar or Automatic Radar Plotting Aid (ARPA). However, any combination of geography (signal blockage), distance, or atmospheric conditions could degrade or even prevent obtaining this information using the radar. The ship's name, call sign or draft could be obtained from a shore facility like a Vessel Traffic Service (VTS). However, these shore-based systems are available only in selected areas. They cover only out as far as their shore-based radars allow. As a last resort, the mariner could attempt to hail the other vessel using the ship's radio. However, this is often time consuming and potentially confusing when in a low visibility situation or when traveling at high speeds. With AIS technology, all this information will be routinely and automatically delivered to the AIS-equipped mariner.

Figure 4. Abbreviated vessel name appears only when the cursor is over the vessel icon

If the AIS successfully provides the mariner with all the above-mentioned information, the issue becomes how to manage all of this useful information. How is it meaningfully displayed to the satisfaction of all the different sub-communities in the maritime industry?[12] Outlined below are suggestions and findings from our work in San Francisco, combined with comments from the BAFEGIS Project and the British Columbia tests on these same display issues and other issues related to the mariner's working environment.

5.1 How much is too much? Vessel Icons and Information

The general operator consensus for labeling vessel icons is to keep the clutter to a minimum and either display the vessel name or the name and call sign. For our research in San Francisco, the operators prefer not to display a vessel name, unless the vessel is selected with the mouse as shown in Figure 4. All additional vessel information, such as length, beam, draft, etc., should be accessible from an additional window or by selecting the vessel with the mouse. An example of

[12] There are several schools of thought as to where and how AIS information should be displayed. This report will focus only on stand-alone displays. No mention will be made of incorporating other sources of information such as ARPA or ECDIS. Both ARPA and ECDIS are potential sources of information for AIS as well as potential display sources.

this is shown in Figure 5. Here a Vessel Data Card or VDC is "tagged" to the vessel icon. The VDC, in this case, contains the vessel's length over all (LOA), beam, draft, navigational status, COG, and SOG information.

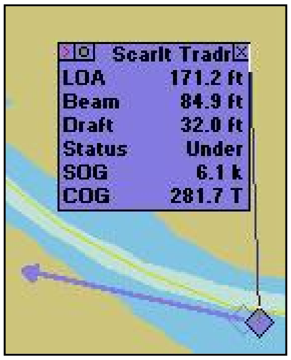

Figure 5. Additional information can be displayed in an information window

Also shown in Figure 5, extending from the vessel icon, is the vessel's COG and "speed" vector. The vector length represents the distance the icon will move in three minutes based on the last COG. AIS allows a heading input as well. This provides, "at a glance," the general direction of travel and approximate future location of the vessel. "At a glance" display design seems to be an important concept. Operators have no time to devote to display options during normal operation. In particular, "at a glance" information is important when traveling at high speeds. The BAFEGIS report makes mention of vector "jitter" or the fact that the vector direction rapidly "walks" back-and-forth for vessels transiting at high speeds. They found this an annoyance and possibly a distraction for the operator. This observation is not the same in San Francisco. The update rate is every 15 seconds and is not speed sensitive as it is in the BAFEGIS operation. Because the update rate is every 15 seconds, the COG vector does not change direction as often.

The British Columbia report suggests relative bearing and range be included from the "own-ship" icon to the other icons displayed or selected. If the vessels are overlaid on some type of geographic reference like a chart, this relationship of relative bearing and distance should be apparent. The participants in San Francisco reported all utilities, such as the range and bearing calculator, a distance scale, and a latitude/longitude indicator, as simply "useful tools," but not features useful while piloting.

Some additional questions that are being further investigated are: When does the mariner become saturated with information on the display? How does the mariner compensate for the increase in information provided? What happens when the screen is cluttered with contacts? How should the display "filter" the unwanted information? These questions have yet to be answered.

5.2 Voice reports provided from the VTS data base

VTS radar coverage in San Francisco Bay does not include the entire VTS waterway. In the areas where there is no radar coverage, the VTS tracks vessels using voice reports provided from the vessels as they pass various reporting points in the waterway. Fast ferries are also tracked in this way. To help the operators maintain awareness of where these vessels are, the VTS data base uses the reported vessel's position and speed at the reporting points to essentially dead reckon or DR an icon representing the vessel on the operator's display. Figure 6 shows the fast ferry MARE ISLAND as both a transponder-tracked target (in blue with the first letter capitalized on the left) and as a voice report (in pink with lower case letters) on the right. The voice report COG and SOG are not the actual COG and SOG from the vessel. The operator enters them in as a "standard track" when the vessel checks in along a predetermined route. A standard track moves a vessel icon on a virtual track from one point to another at a specified speed.

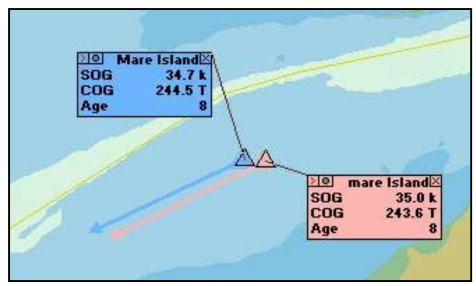

Figure 6. A Voice Report and a Transponder report from the same vessel

Figure 6 also shows close agreement between the actual and voice reports. This is not the normal condition. The vessels often do not closely follow the standard tracks. Standard track lines are only a VTS operator's tool. Variations in position between a transponder report and a voice report are often large especially if the vessels change either course or speed between position reports to the VTS. The two positions can also vary if the vessel operator reports early or late at the reporting point. Presently, voice reports are being provided to the participants in San Francisco. The display software allows users to filter these reports from their display. In general, most participants "on the water" do not find the voice reports accurate enough to describe the position of the vessel. They choose not to include this information on their displays. However, this information does seem to be very useful to shore facilities, such as the VTS operators and dispatchers who need a method to manage non-radar tracked vessels.

5.3 Professional Pilot's Display -- Smaller, Simpler, and Lighter

Issues surrounding pilot carry-aboard units and displays have been discussed with several San Francisco Bar Pilots. Most pilots are looking for a lightweight, accurate, rugged information system that can be quickly set up. This system should provide not only "own ship" information, including DGPS and heading data, but movement data from other vessels as well. The pilots also find real-time information about hydrographic and meteorological information, such as NOAA PORTS and NDBC buoy data, very useful.

As part of our testing with the San Francisco Bar pilots, we looked at using a Mitsubishi™ mini-laptop that ran our display program. The primary limitation is battery life. We found that for a 6-hour transit it is necessary to carry almost ten pounds of sealed lead-acid batteries to power the computer, DGPS receiver, and antenna.[13] As personal computer (PC) technology improves and DGPS receivers become smaller, the weight of these units will decrease considerably, but is this the correct long-term solution? The realistic objective should be to provide the pilots with the information they need to do their job using lightweight, low-powered equipment that requires minimum setup time.

Here again, AIS may ultimately provide the answer. The pilots are looking for a simple display that relates the movement of the vessels in the waterway. AIS may be the basic technology for gathering the information, but may not be the best information delivery tool. In terms of portability, one of the drawbacks to an AIS unit is the battery weight needed to power the two VHF receivers and one transmitter internal to the unit itself. In terms of setup, access to all the desired shipboard sensors, such as heading, may not be possible on all ships. For pilots, it may be better to process the available AIS data on shore and send custom reports back to the pilots through a commercial wireless service. The features and operation of such a system would be the responsibility of the pilots and they would customize it to their specific needs. The details of the

[13] This weight can be reduced with a better choice of battery.

necessary data processing and transfer would be their responsibility. However, the information source for their system would be the AIS signals broadcast by the ships' AIS units.

The data connection used by the pilots could be a commercial digital communications system that would not load down or interfere with the AIS channels.

With a shore-based information source, the portable display portion of the pilot's unit may be as simple as a miniature PC that receives the shore-processed data from a wireless service like a WISP, cell phone, or satellite phone. The display can be an off-the-shelf charting program, or tables and lists that are custom designed to the pilot's and waterways requirements. A second solution is the use of a handheld personal digital assistant (PDA). This technology has the capability to send and receive small amounts of data using cell phone technology. This data could then be displayed either as a very simple chart or textually. Text may be sufficient to answer the question: Where are other large vessels in the waterway? This approach may not provide timely "own ship" heading or DGPS position information, but it could provide data about other ships as well as NOAA PORTS and NDBC Buoy data. Again, the importance here is to provide the mariner with the information they need on a low power, lightweight display.

Other AIS and enhanced AIS issues exist. For example, this summary does not address the information issues surrounding the shoreside of the marine community. Some issues are: How do shore managers, like dispatchers and agents, use AIS data to better coordinate their vessels? How does AIS impact the intermodal infrastructure by providing timely cargo information? How should AIS information be linked to the intermodal infrastructure? How should the USCG link AIS information to search and rescue, and pollution response operations?

5.4 Route and Destination

All three studies agree that the vessel's destination should be available but not displayed until requested by the user. The destination information, in some cases, will make it easier to forecast a possible meeting situation. AIS will allow the mariner to enter destination information. AIS should not be used to provide information about planned vessel routes or track lines. The British

Columbia test concluded that the route information would, at times, be unreliable and should not be included.

5.5 Meeting Situations and CPA

The research in San Francisco exposed the need for a function to calculate the place and time when two or more vessels were likely to meet - a function requested by the pilots. Frequently termed Closest Point of Approach or CPA, this meeting point would give valuable collision avoidance information with a few restrictions. CPA is a good collision avoidance tool for vessels in open water. However, it tends to have less relevance when vessels are separated by great distance. In this case either vessel has the opportunity to change course and speed several times before the eventual meeting.

Standard track lines or routes can also provide assistance in determining where vessels are likely to meet – assuming the vessels follow the tracks. Since AIS will not provide information as to a vessel's future or intended route, there is no way to predict where a meeting will occur. This presents a problem in congested harbors. In narrow waterways, standard track lines may provide a solution to the problem of where two vessels will likely meet.

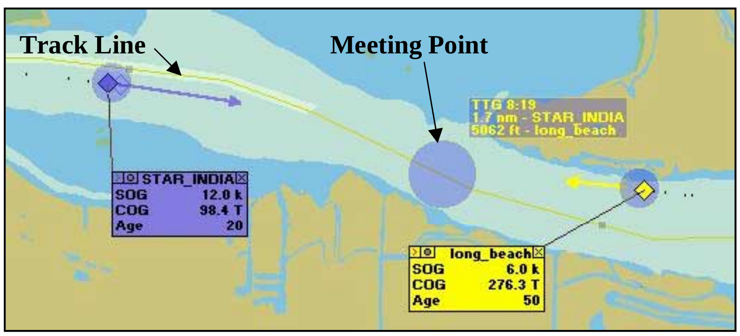

Figure 7. Using a track line in a narrow channel to help define a meeting point and time

Figure 7 shows the case where two vessels are approaching in a narrow channel labeled with a track line down the center. Both vessels are right of the track line. In this case, the purple circle between the vessels on the track line represents the meeting point. The meeting time as well as the vessels' respective distances to reach the meeting point are labeled in the box above and to the right of the purple circle. Note that this is not CPA since the meeting point is shown on the track line. CPA might be very close to this meeting point in this case, but CPA does not take into account a vessel's intended track or "best water." In this case, the CPA might be outside the channel.

It is important to note two things in this situation. First, the vessels are in a narrow channel. The calculation assumes the vessels travel along their track lines. Both vessels are navigating in the channel towards one another and there are no alternatives but to stay inside the bounds of the channel. Second, the calculation is for a meeting point on a fixed track line. The assumption is that the track line runs down the center of "best water." A useful example may be when two vessels are out of sight visually or with radar in a narrow channel or river. A meeting point feature would give the location on the track line where the two vessels would likely meet. This point may be "around the bend" and out of sight visually or by radar from one or both of the vessels. In this case, both AIS-equipped vessels would have the information to make timely alternate passing arrangements or speed adjustments as necessary.

5.6 Access to the Vessel Data Storehouse: Relaying Target Information

If there is a VTS in a port, the British Columbia report and the group in San Francisco both felt strongly that the shore radar target information from the VTS should be provided to the AIS unit. However, the converse is not true. They felt that individual ships should not rebroadcast their own radar targets, for reliability reasons. This latter concern is not significant. AIS does not provide for the rebroadcast of vessel radar or ARPA data.

When the San Francisco Bay experiment started, the participants only had access to nine vessel reports from the vessels equipped with the AIS-like devices. They saw these reports as an interesting experiment but not terribly useful. They still were not able to see all the targets that impacted their jobs. It wasn't until we incorporated the radar data, tagged with the vessel's name, COG and SOG from the VTS, that they started to take more operational interest in the technology. With the addition of "large ship" information, they began to understand how AIS might impact their safety and mobility. It is worth mentioning here that the radar targets themselves, lacking vessel's name, COG and SOG, provided little additional benefit. The real benefit came from associating a vessel name with the target, information added by the VTS operator, and other information like COG and SOG. Without the vessel name, the mariner is still faced with the vessel identity question.

In all three groups, the overwhelming response was that AIS would give the mariner and the VTS operator a better picture of what is happening in the waterway. The AIS display should be as simple or involved as the user requires. Vessel icons, both transponder and radar target, should be labeled with the vessel's name and a vector representing the anticipated movement of the vessel.

Enhanced AIS provides many additional opportunities to integrate data useful to the mariner. Where available, every effort should be made to incorporate weather and hydrographic data into the AIS display. Enhanced AIS can also be used to provide lightweight portable displays by collecting and processing the AIS data on shore and then transmitting it to the user's display device.

The reaction of the San Francisco Bay demonstration participants strongly suggests that AIS is going to be an enabling technology. That is, the user community is finding ways to apply the technology to their operations in ways that benefit them that were not initially recognized at the time the technology was defined. Hopefully, these fresh ideas can continue to be captured through forward-looking experiments such as those in the Baltic Sea, British Columbia, and San Francisco.

Combining AIS and radar information is an issue. How should two reports about the same contact – one AIS and the other from VTS radar, be displayed? In San Francisco, both are displayed. Figure 8 shows the tug CLAUDIA FOSS, as both a VTS radar target (in yellow) marked with the VDC in all capital letters and a transponder target (in green) marked with the VDC with a mix of capital and lower case letters.

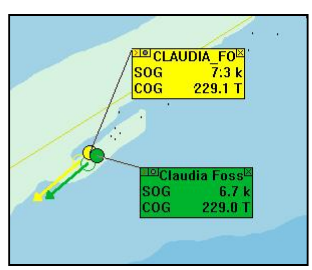

Figure 8. An example of the same vessel reported by both a transponder and by VTS radar

The British Columbia test recommends the consolidation of these targets into one icon under certain constraints. To avoid improper consolidation of targets, they suggest using the distance between the targets, the variation of the targets' COG and SOG, as well as the trends of these values over a certain number of updates, as criteria to consolidate. If the targets simultaneously meet the criteria above, they would be automatically consolidated. If they did not meet the criteria, they would be displayed separately as in figure 8. There are currently very few multiple contact situations in San Francisco. The San Francisco participants have not raised this issue. We have found that showing both reports has not led to any confusion.

5.7 More Equipment: Operator Stress and Increased Workload

Often with the addition of technical systems involving electronics and computers like AIS, ECDIS, ARPA, etc., there exists the potential for added stress. This stress is brought about by the additional responsibilities to operate the equipment. Initial AIS tests in the Baltic Sea and British Columbia and ongoing AIS tests in San Francisco show that AIS does not increase the stress on the operator once they are trained on both the display interface as well as the AIS unit itself. In fact, in most cases they feel less stress during their watches because they have better, immediate access to the vessel data they need - especially at night and in areas of low visibility. A respondent from the BAFEGIS project said he “can continually watch the accuracy of the system and can easily see the connection with the radar screen.” AIS also decreases the need for VHF communications, increases perceived safety in almost any condition of visibility or daylight, and improves operator efficiency.

5.8 Surveillance Issues

In 1997, at the beginning of the San Francisco Bay demonstration, several of the operators reported uneasiness with the idea that their home office or the VTS was monitoring them. Now, however, the participants in San Francisco do not report any added stress because the VTS, their home office, or other vessels are monitoring them. This feeling was also confirmed in the BAFEGIS project. Operators feel that if you follow procedures for safe navigation, surveillance is not an issue.

Despite the operators' comfort level, the issue remains: Could AIS be used as a Vessel Data Recorder to play back incidents, or near misses? This question has come up several times during the San Francisco Bay tests. DGPS information is used routinely to settle admiralty court cases.

The answer here is, "yes." AIS data could be used in this manner. We have discussed the fact that AIS information is digital and can be viewed, recorded and played back virtually anywhere.

5.9 Safety: How close is too close?

Collisions and Allisions - AIS is primarily a source of navigation and situation information for vessels. But if the data is placed in the right frame of reference, like on an electronic chart, it can also be used as a navigation system. This topic was addressed in the BAFEGIS report and with the participants in San Francisco. They were asked if their “safety distance,” or the distance to vessels and other navigation hazards, changed after they began using the AIS data? Both groups reported that their safety distance remained unchanged. They also reported a positive effect on safety during periods of heavy traffic, reduced visibility, and daylight.

Overhead Clearance – As far as safety margins go, there are locations where limiting safety margins to only two dimensions, in the horizontal plane, falls short of the true requirement. The prudent metric for a vessel is to view hazards in a three-dimensional reference plane. The third dimension produces a “safety sphere” enclosing the vessel. The sphere represents not only safety distance in the horizontal plane but under keel and overhead clearance in the vertical plane. The group in San Francisco has requested that future work produce real-time information relating to bridge clearance. In San Francisco, bridge clearance calculation is an issue when taking vessels to ports such as Sacramento and Stockton, California. If systems were in place to report accurate bridge clearance information, this information could be sent to the AIS units as a safety-related broadcast message. Again, this is another enhanced AIS issue to be explored.

Fatigue Reduction - The response in San Francisco to the AIS-like data has also been positive from the mariners faced with an imposed 12-hour workday limit during a 24-four hour period. With access to the actual movement data from other vessels, operators can better plan the timing of their next job. The vessel position information can tell them accurately how much time they need to allow in order to meet their next job without having to unnecessarily rush to finish their current one. Here, AIS provides information that allows operators to effectively manage resources while reducing stress, thus improving safety.

5.10 Communications: Does AIS reduce VHF-FM calls?

VHF bridge-to-bridge and VHF ship-to-shore communications are a primary means for mariners to communicate with other vessels, shore facilities, and the VTS. From the BAFEGIS study and our work in San Francisco, early indications are that the addition of AIS data has reduced VHF radio communication slightly, and at the same time, made it more efficient. Less information needs to be passed. This results in fewer calls made over the radio. In San Francisco, the mariners also felt less of a need to contact the VTS or the Marine Exchange directly to get information concerning ship's position and movement. A tug captain with 23 year's experience explains, "I don't need to bother the VTS [operations] people with arriving ships' positions. They, at times, don't need the added workload." A slight decrease in VHF traffic was felt at both the VTS and Marine Exchange. Also, the number of telephone calls from the dispatchers and Marine Exchange to the VTS have been reduced since they began looking at the AIS-like data on their TransView displays.

6. FUTURE WORK

The issues presented and discussed here represent a small fraction of the possibilities AIS represents. Work still needs to be done in the areas of:

- Enhanced AIS issues, including:
  - direct sensor information,
  - shore radar information,
  - security issues,
  - sending proprietary information,
  - Maritime Transportation System (MTS) intermodal integration, and
  - search and rescue and environmental responses.

- Integrating real-time information such as NOAA PORTS data, bridge clearance information, water height levels, etc., into the AIS VHF data-link.
- Using actual AIS data to drive ship simulators and to create training scenarios.
- Using actual AIS data to evaluate and test suggested changes in waterway configurations and other forms of traffic management.
- Accessing actual traffic patterns in a waterway to evaluate the environmental impact of additional commercial vessels.

7. CONCLUSIONS

In all three studies, the overwhelming response was that AIS would give the mariner and the VTS operator a better picture of what is happening in the waterway. This display should be as simple or involved as the user requires. Vessel icons, both transponder and radar target, should be labeled with the vessel's name and a vector representing the anticipated movement of the vessel. Enhanced AIS provides many additional opportunities to integrate data useful to the mariner. Where available, every effort should be made to incorporate weather and hydrographic data into the AIS display. AIS can also be used to provide lightweight portable displays by collecting and processing the AIS data on shore and then transmitting it to the user's display device. Initial AIS tests in the Baltic Sea and British Columbia and ongoing AIS tests in San Francisco show that AIS does not increase the stress on the operator once they are trained on both the display interface as well as the AIS unit itself. AIS decreases the need for VHF communications, increases perceived safety in almost any condition of visibility or daylight, and improves operator efficiency.

The reactions of the San Francisco Bay demonstration participants strongly suggest that AIS is going to be an enabling technology. That is, the user community is finding ways to apply the technology to their operations in ways that benefit them that were not initially recognized at the time the technology was defined. Hopefully, these fresh ideas can continue to be captured through forward-looking experiments such as those in the Baltic Sea, British Columbia, and San Francisco.